# Assignment -1

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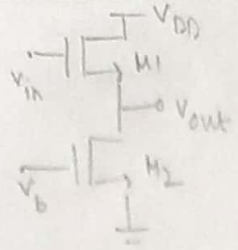
1.a)

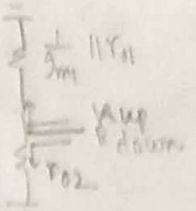



$G_m = g_{m1}$

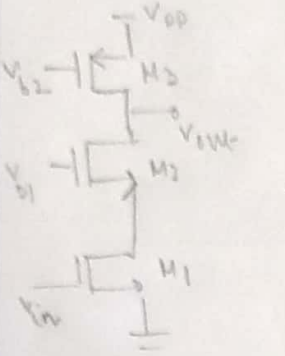
$R_{down} = r_{o2}$

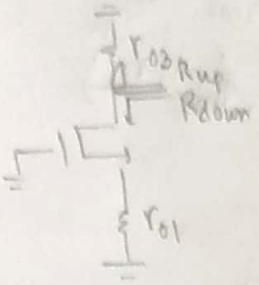
$R_{up} = \frac{1}{g_{m1}} \| r_{o1}$

$R_{out} = \frac{1}{g_{m1}} \| r_{o1} \| r_{o2}$




b)




$G_m = g_{m1} \frac{r_{o1}}{r_{o1} + \left(\frac{1}{g_{m2}} \| r_{o2}\right)} \approx g_{m1}$

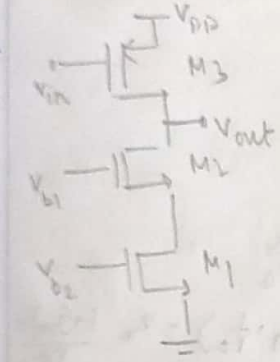
$R_{up} = r_{o3}$

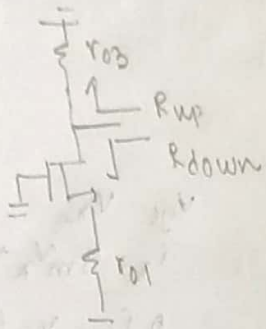
$R_{down} = r_{o2} + r_{o1} + g_{m2} r_{o2} r_{o1}$

$R_{out} = r_{o3} \| (r_{o1} + r_{o2} + g_{m2} r_{o2} r_{o1})$

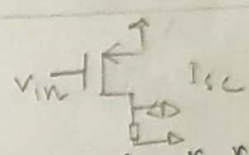
$\approx r_{o3} \| g_{m2} r_{o2} r_{o1}$

c)




$G_m = g_{m3}$



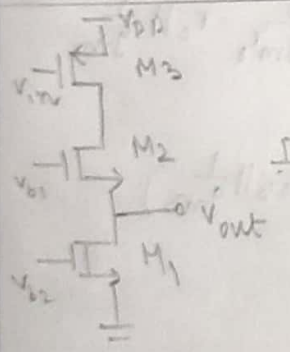

$R_{up} = r_{o3}$

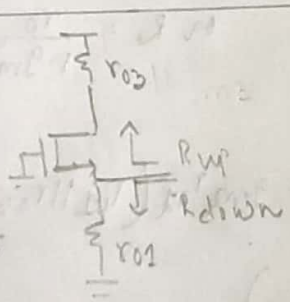
$R_{down} = r_{o2} + r_{o1} + g_{m2} r_{o2} r_{o1}$

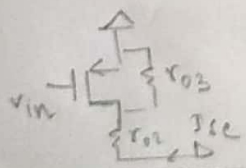
$R_{out} = r_{o3} \| (r_{o1} + r_{o2} + g_{m2} r_{o1} r_{o2})$

$\approx r_{o3} \| g_{m2} r_{o1} r_{o2}$

d)




$G_m = g_{m3} \frac{r_{o3}}{r_{o3} + r_{o2}}$

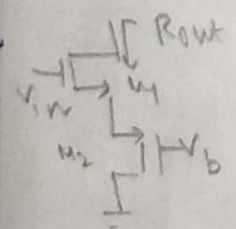
$R_{up} = \frac{r_{o2} + r_{o3}}{1 + g_{m2} r_{o2}} = r_{o2} \| \frac{1}{g_{m2}} + \frac{r_{o3}}{1 + g_{m2} r_{o2}}$

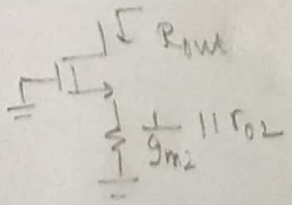
$R_{down} = r_{o1}$

$R_{out} = r_{o1} \| \left( r_{o2} \| \frac{1}{g_{m2}} + \frac{r_{o3}}{1 + g_{m2} r_{o2}} \right)$

$= r_{o1} \| \frac{r_{o2} + r_{o3}}{1 + g_{m2} r_{o2}}$

2.a)



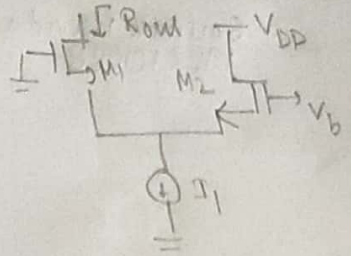

$R_{out} = r_{o1} + R_S + g_{m1} r_{o1} R_S \qquad R_S = \frac{1}{g_{m2}} \| r_{o2}$

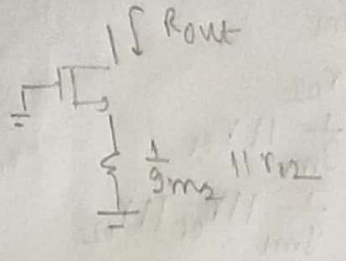
$\approx \cancel{g_{m1} r_{o1} R_S}$

$= r_{o1} + \frac{1}{g_{m2}} \| r_{o2} + g_{m1} r_{o1} \left( \frac{1}{g_{m2}} \| r_{o2} \right)$

$\approx g_{m1} r_{o1} \left( \frac{1}{g_{m2}} \| r_{o2} \right)$

b)



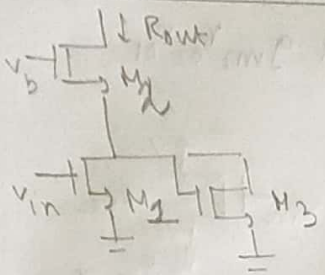



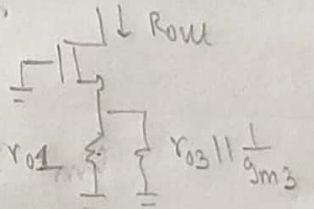

$$R_{out} = r_{o1} + R_S + g_{m1} r_{o1} R_S \qquad R_S = \frac{1}{g_{m2}} \| r_{o2}$$

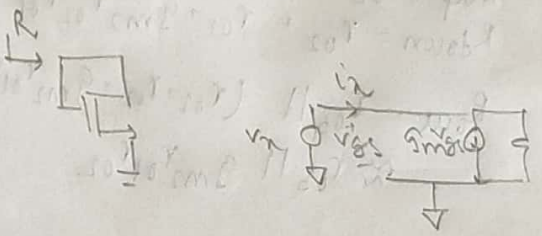
$$= r_{o1} + \frac{1}{g_{m2}} \| r_{o2} + g_{m1} r_{o1} \left( \frac{1}{g_{m2}} \| r_{o2} \right)$$

$$\approx g_{m1} r_{o1} \left( \frac{1}{g_{m2}} \| r_{o2} \right)$$

c)




$$v_{gs} = v_x$$

$$i_x = g_m v_x + \frac{v_x}{r_o}$$

$$\text{or } i_x = v_x \left( g_m + \frac{1}{r_o} \right) = v_x \frac{1 + g_m r_o}{r_o}$$

$$\text{or } R = \frac{r_o}{1 + g_m r_o} = r_o \| \frac{1}{g_m}$$

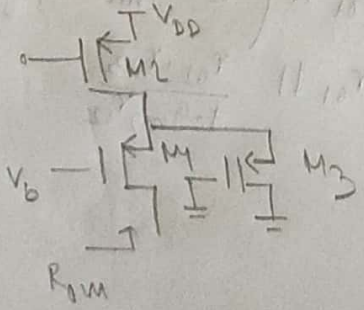
$$R_S = r_{o1} \| r_{o3} \| \frac{1}{g_{m3}}$$

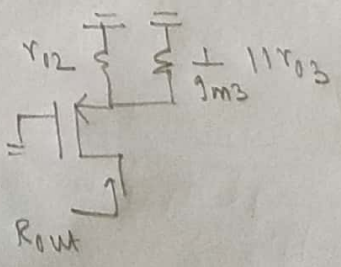
$$R_{out} = r_{o2} + R_S + g_{m2} r_{o2} R_S$$

$$= r_{o2} + \left( r_{o1} \| r_{o3} \| \frac{1}{g_{m3}} \right) + g_{m2} r_{o2} \left( r_{o1} \| r_{o3} \| \frac{1}{g_{m3}} \right)$$

$$\approx g_{m2} r_{o2} \left( r_{o1} \| r_{o3} \| \frac{1}{g_{m3}} \right)$$

d)



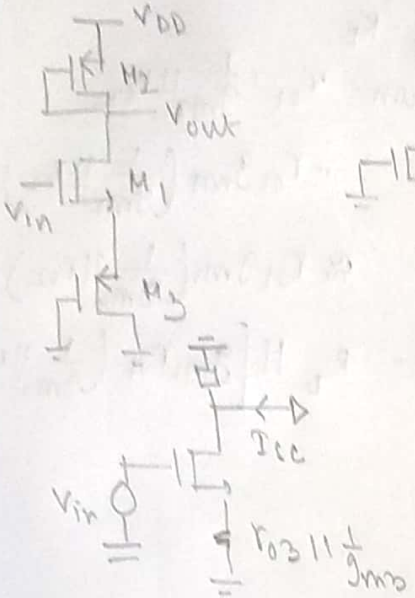

$$R_S = r_{o2} \| r_{o3} \| \frac{1}{g_{m3}}$$

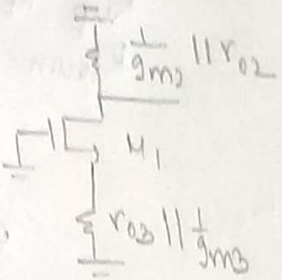
$$R_{out} = r_{o1} + R_S + g_{m1} r_{o1} R_S$$

$$= r_{o1} + \left( r_{o2} \| r_{o3} \| \frac{1}{g_{m3}} \right) + g_{m1} r_{o1} \left( r_{o2} \| r_{o3} \| \frac{1}{g_{m3}} \right)$$

$$\approx g_{m1} r_{o1} \left( r_{o2} \| r_{o3} \| \frac{1}{g_{m3}} \right)$$

a)




$$R_{up} = \frac{1}{g_{m2}} \| r_{02}$$

$$R_{down} = r_{01} + r_{03} + g_{m1} r_{01} \left(r_{03} \| \frac{1}{g_{m3}}\right)$$

$$R_{out} = \frac{1}{g_{m2}} \| r_{02} \| \left(r_{01} + r_{03} + g_{m1} r_{01} r_{03} \| \frac{1}{g_{m3}}\right)$$

$$\approx \frac{1}{g_{m2}} \| r_{02} \| \left[g_{m1} r_{01} \left(r_{03} \| \frac{1}{g_{m3}}\right)\right]$$

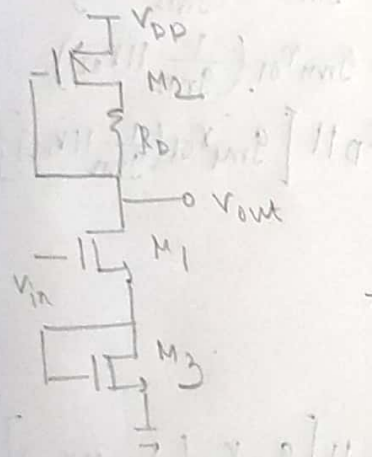
$$G_m = \frac{g_{m1}}{1 + g_{m1}\left(r_{03} \| \frac{1}{g_{m3}}\right)}$$

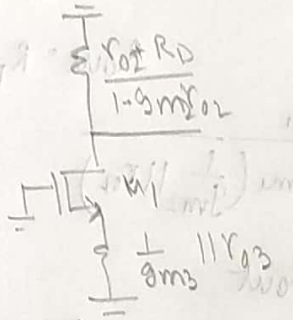
$$A_V = -G_m R_{out}$$

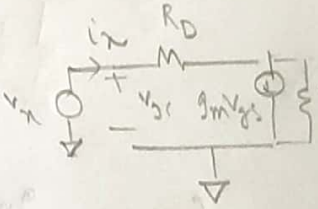
$$= -\frac{g_{m1}}{1 + g_{m1}\left(r_{03} \| \frac{1}{g_{m3}}\right)} \left( \frac{1}{g_{m2}} \| r_{02} \| r_{01} + r_{03} + g_{m1} r_{01} r_{03} \| \frac{1}{g_{m3}} \right)$$

$$\approx -\frac{g_{m1}}{1 + g_{m1}\left(r_{03} \| \frac{1}{g_{m3}}\right)} \left( \frac{1}{g_{m2}} \| r_{02} \| g_{m1} r_{01} \left(r_{03} \| \frac{1}{g_{m3}}\right) \right)$$

b)




$$V_{gs} = V_x$$

$$i_x = g_m V_x + \frac{V_x - i_x R_D}{r_o}$$

$$\Rightarrow i_x \left(1 + \frac{R_D}{r_o}\right) = V_x \left(g_m + \frac{1}{r_o}\right)$$

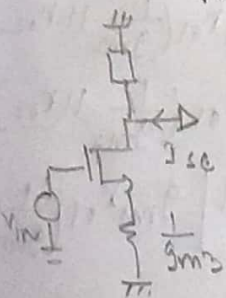
$$\Rightarrow R = \frac{1 + R_D/r_o}{\frac{1}{r_o} + g_m} = \frac{r_o + R_D}{1 + g_m r_o}$$

$$R_{up} = \frac{r_{02} + R_D}{1 + g_{m2} r_{02}}$$

$$R_{down} = r_{01} + \left(\frac{1}{g_{m3}} \| r_{03}\right) + g_{m1} r_{01} \left(\frac{1}{g_{m3}} \| r_{03}\right)$$

$$\approx g_{m1} r_{01} \left(\frac{1}{g_{m3}} \| r_{03}\right)$$

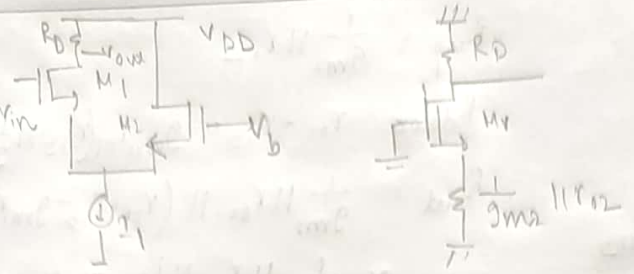
$$R_{out} = \frac{r_{02} + R_D}{1 + g_{m2} r_{02}} \| \left[ g_{m1} r_{01} \left(\frac{1}{g_{m3}} \| r_{03}\right) \right]$$




$$G_m = \frac{g_{m1}}{1 + g_{m1}\left(\frac{1}{g_{m3}} \| r_{03}\right)}$$

$$A_V = -G_m R_{out}$$

c)





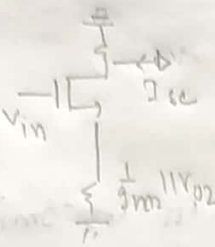


$R_{up} = R_D$

$R_{down} = r_{o1} + \frac{1}{g_{m2}} \| r_{o2} + r_{o1} g_{m1} \left(\frac{1}{g_{m2}} \| r_{o2}\right)$

$\approx r_{o1} g_{m1} \left(\frac{1}{g_{m2}} \| r_{o2}\right)$

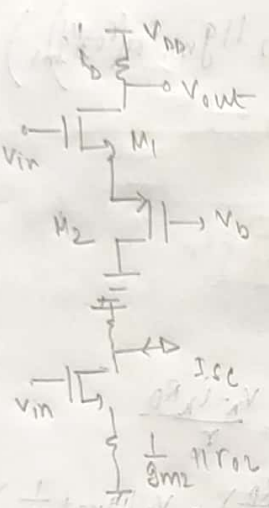
$R_{out} = R_D \| \left[ g_{m1} r_{o1} \left(\frac{1}{g_{m2}} \| r_{o2}\right)\right]$

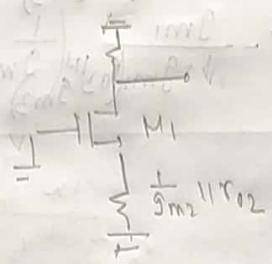



$G_m = \frac{g_{m1}}{1 + g_{m1}\left(\frac{1}{g_{m2}} \| r_{o2}\right)}$

$A_V = -g_m G_m R_{out}$

d)




$R_{up} = R_D$

$R_{down} = \frac{1}{g_{m2}} \| r_{o2} + r_{o1} + g_{m1} r_{o1} \left(\frac{1}{g_{m2}} \| r_{o2}\right)$

$\approx g_{m1} r_{o1} \left(\frac{1}{g_{m2}} \| r_{o2}\right)$

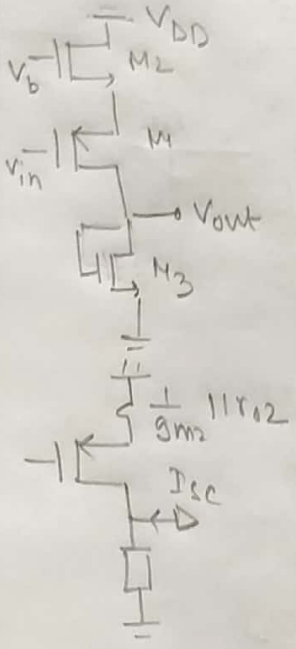
$R_{out} = R_D \| \left[ g_{m1} r_{o1} \left(\frac{1}{g_{m2}} \| r_{o2}\right)\right]$

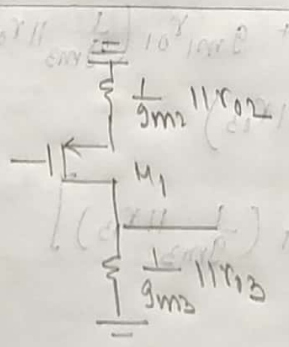
$G_m = \frac{g_{m1}}{1 + g_{m1}\left(\frac{1}{g_{m2}} \| r_{o2}\right)}$

$A_V = -G_m R_{out}$

$\therefore \frac{-g_{m1}}{1 + g_{m1}\left(\frac{1}{g_{m2}} \| r_{o2}\right)} \left\{ R_D \| \left[ g_{m1} r_{o1} \left(\frac{1}{g_{m2}} \| r_{o2}\right)\right]\right\}$

e)




$R_{down} = \frac{1}{g_{m3}} \| r_{o3}$

$R_{up} = r_{o1} + \frac{1}{g_{m2}} \| r_{o2} + g_{m1} r_{o1} \left(\frac{1}{g_{m2}} \| r_{o2}\right)$

$\approx g_{m1} r_{o1} \left(\frac{1}{g_{m2}} \| r_{o2}\right)$

$R_{out} = \frac{1}{g_{m3}} \| r_{o3} \| \left[ g_{m1} r_{o1} \left(\frac{1}{g_{m2}} \| r_{o2}\right)\right]$

$G_m = \frac{g_{m1}}{1 + g_{m1}\left(\frac{1}{g_{m2}} \| r_{o2}\right)}$

$A_V = -G_m R_{out}$